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# COMPARISON OF METHODS FOR DISINFECTING SWIMMING POOLS *

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## ULTRA VIOLET LIGHT

Ultra violet light has been used abroad for the disinfection of drinking water and in Paris for the disinfection of a swimming pool. In this country, where it has recently been introduced, its application to the disinfection of swimming pools is the most modern device adopted for that purpose. In the matter of operation and handling, ultra violet light would be the most satisfactory method of disinfection thus far introduced. In the first place, nothing which could arouse objection from bathers is added to the water, and in the second place it is automatic—neither too much nor too little could be added by a possibly bungling attendant, since after turning on the light, he would need to give no further attention to the apparatus. Accordingly, the determination of its cost of operation, bacterial efficiency, etc., have been investigated with the utmost interest.

*Tests at the 57th Street Y. M. C. A.*—The capacity of this pool is approximately 75,000 gallons. The water is circulated through the filters every 24 hours and is thereby maintained clear. It is drawn from the bottom of the deep end and returned after filtration to the surface of the shallow end, being there discharged from a pipe about 2 feet above the surface of the pool, the latter measure insuring considerable aeration of the water. At the time of these tests the water had been in the pool for about 6 months.

Samples of water were collected from the pool at the deep end, from a tap on the pipe returning from the filter, and from the pipe discharging into the pool after the water had been exposed to the ultra violet light. From the analyses of these samples it was possible to determine the number of bacteria in the pool, the amount of reduction due to refiltration, and the amount of reduction, if any, due to exposure to the ultra violet light. Similar analyses were made in all tests on ultra violet light.

Series 1. A count of 20 bacteria to the cubic centimeter in water from the pool at 37 C., was reduced by filtration to 5, and by exposure to ultra violet light, to 2. This reduction of 3 bacteria to the cubic centimeter as a result of exposure to the light, in plate counts might readily be attributed to normal experimental error in pouring plates.

Series 2. Here a count of 250 bacteria to the cubic centimeter for the pool sample at incubator temperature fell to 40 during filtration, and rose

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TABLE 1

BACTERIAL COUNTS IN Y. M. C. A. POOL AFTER INSTALLATION OF VIOLET LIGHT APPARATUS *

| Source of Sample Tested | 1st Series | | 2nd Series | | | 3rd Series | | |
|---|---|---|---|---|---|---|---|---|
| | 37 C. | Colon Bacilli per c.c. | 37 C. | 20 C. | Colon Bacilli per c.c. | 37 C. | 20 C. | Colon Bacilli per c.c. |
| From pool........ | 20 | 0 | 250 | 231 | 0 | 150† | 416† | ½ |
| From filter........ | 5 | 0 | 40 | 32 | 0 | 5 | 52 | 0 |
| From violet light. | 2 | ½ | 42 | 53 | 1 | 15 | 70 | 0 |

* Water in pool 6 months. † Pool had been agitated by scooping up dirt from bottom.

BACTERIAL COUNTS IN THE SAME POOL BEFORE USE OF ULTRA VIOLET LIGHT FOR DISINFECTION ‡

| Day of Test | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th |
|---|---|---|---|---|---|---|---|
| At 37 C. | 30 | 700 | 4000 | 2500 | 2600 | 5000 | 14000 |
| At 20 C. | 300 | 6000 | 44000 | 150000 | 150000 | 170000 | 31000 |

‡ Pool emptied every 2 weeks.

slightly, to 42, after exposure to the ray. The room-temperature counts showed about the same result—231 bacteria to the cubic centimeter in the pool sample, 32 in the sample from the filter, and 53 in the sample after exposure to the lights.

Series 3. In this series the results were approximately the same as before. The water in the pool, which had been agitated by scooping dirt from the bottom, contained 150 bacteria to the cubic centimeter at 37 C. and 416 at 20 C. After filtration the counts were 5 and 52, respectively, and after exposure to the ray 15 and 70. Colon bacilli were irregularly present in the 1-c.c. samples.

*Tests at the New York Athletic Club.*—In order more thoroughly to investigate the value of the machine for disinfection of water, additional series of tests were planned at the New York Athletic Club.

Series 1. Water from the pool gave a count at 37 C. of 345 bacteria to the cubic centimeter, and at 20 C. of 880 bacteria to the cubic centimeter. After refiltration the counts were 250 and 500. After exposure to the ray the counts were 240 and 730.

Series 2. The experiment was repeated as a control before adding a large number of colon bacilli to the water. Again there was no noticeable reduction in the bacterial counts after exposure to the ray.

Series 3. In order to produce test conditions under which results would be more striking, a large number of colon bacilli from a stock culture grown on agar were added to the pool. The data obtained indicate that while the filters were chiefly responsible for the reduction, the ultra violet light did play some part in lowering the counts.

The shortness of the time of exposure of the water to the light probably accounts for the rather poor results. That the machine is of some value in purifying the water is evident from a comparison of the bacterial counts taken at the 57th street Y. M. C. A. before the apparatus had been installed with those after the machine was in use (Table 1). The difference between the two groups is striking. Since

TABLE 2

Bacterial Counts in N. Y. A. C. Pool after Installation of Ultra Violet Light Apparatus

| Source of Sample Tested | 1st Series | | | 2nd Series | | | 3rd Series* | | |
|---|---|---|---|---|---|---|---|---|---|
| | 37 C. | 20 C. | Colon Bacilli per c.c. | 37 C. | 20 C. | Colon Bacilli per c.c. | 37 C. | 20 C. | Colon Bacilli per c.c. |
| From pool........ | 345 | 880 | 0 | 600 | 620 | 0 | 3780 | 2400 | 1000 |
| From filter........ | 250 | 500 | 0 | 240 | 470 | 0 | 240 | 470 | 10 |
| From violet light | 240 | 730 | 0 | 200 | 450 | 1 | 200 | 450 | 1 |

* Colon bacilli added to the pool.

Bacterial Counts in the Same Pool before the Use of Ultra Violet Light for Disinfection †

| Day of Test | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th |
|---|---|---|---|---|---|---|---|---|
| At 37 C. | 150 | 1000 | 200 | 180 | 200 | 300 | 180 | 500 |
| At 20 C. | 350 | 10000 | 6000 | 1000 | 230 | 3000 | 300 | 2000 |

† Pool continuously diluted with warm filtered water, and emptied every 2 weeks.

the use of ultra violet light was the only change in technic, it would appear that this light exerts a steady reducing effect on bacterial pollution.

In the test in the New York Athletic Club the results would point the other way (Table 2). Here, however, the pool when not treated with ultra violet light was continuously diluted with fresh warm water, so that the comparison of bacterial counts before and after, in this instance, is not easily made.

In view of the facts thus far advanced it would seem desirable to increase the time of exposure of the water to the light.

## "LECTROCIDE"

"Lectrocide" is a chemical manufactured through electrolysis of brine water (sea water). It is a greenish chemical with a chlorin odor, altho its main ingredient is sodium hypochlorite.

Two methods of applying this chemical to the swimming pool were tried: (1) The chemical was introduced into the bottom of the deep end through a long pipe. Water from the pool was then poured through so as to drive the chemical below the surface of the pool. Tests lasting for 1 week were conducted while this method of treating the water was in use. (2) During the following week the chemical was introduced into the water through an automatic feed pot attached to the pipe leading from the filter to the pool. The valve on the feed pot was arranged so that the chemical was completely discharged into the water in 24 hours.

The data collected (see coefficient in Table 3) during 15 days of test indicate that the introduction of this chemical into the water in single daily doses is superior to the slow continuous adding of the chemical from a feed pot.

The lectrocide was added so that there was 1 part of chlorin to 1,000,000 parts of water. The bacterial contamination in the swimming pool when treated with lectrocide remained low throughout the whole series of experiments (Table 2, Nos. 1, 2, and 3).

### COPPER SULFATE

Experiments were conducted with copper sulfate similar to those conducted with lectrocide and similar to those conducted with chlorin gas and calcium hypochlorite, to be described later. The object was to secure data upon which comparison of relative efficiencies could be based.

Copper sulfate in concentration of 1 part in 100,000 parts of water by weight was added to the pool daily. It was dissolved in water and added in the same ways as lectrocide; that is, as a single daily dose for the first week and from the mixing pot as a continuous gradual dose during the second week. In direct contrast to the experiment with lectrocide, here the continuous slow adding of chemical was more effective than single daily dosing. Evidently the efficiency of chemical disinfection is dependent not only on the chemical employed, but on the method of adding it to the water.

The efficiency of copper sulfate itself, however, is low when 1 part in 100,000 is used. Bacterial pollution was higher throughout the 2 weeks of test than it was when sodium hypochlorite was substituted. Furthermore, the cost per day for treatment with copper sulfate was $1.04—nearly 8 times that for treatment with "lectrocide." The water was yellowish and its transparency was reduced to such an extent as to draw complaints from the patrons. When the pool was emptied, the tiles were stained, so that scrubbing with oxalic acid was necessary in addition to the ordinary labor of cleaning the pool. In short, as will be seen later, copper sulfate showed the poorest efficiency and the highest cost of application of all chemicals used in pool-disinfection. (See coefficient values in Table 3. The results with chlorin gas, Table 2, No. 6, should not be included in the comparison because of defective apparatus.)

## TABLE 3

### COMPARISON OF THE RESULTS OF VARIOUS METHODS OF DISINFECTING SWIMMING POOLS

| Day | 1. "Lectrocide" Added in Single Daily Doses | | 2. "Lectrocide" Added in Single Daily Doses | | 3. "Lectrocide" Added From Feed Pot | | 4. Copper Sulfate in Single Daily Doses | |
|---|---|---|---|---|---|---|---|---|
| | 37 C. | 20 C. | 37 C. | 20 C. | 37 C. | 20 C. | 37 C. | 20 C. |
| 1st........... | 350 | 900 | 2800 | 660 | 18000 | 16500 | 3000 | 28000 |
| 2nd........... | 10000 | 8000 | 5200 | 8000 | 5000 | 13200 | 40000 | 84000 |
| 3rd........... | 10000 | 7000 | 2400 | 2700 | 400 | 1400 | 30000 | 72000 |
| 4th.......... | 7500 | 400 | 1800 | 2400 | 80 | 2500 | 30000 | 42000 |
| 5th........... | 200 | 1000 | 660 | 2200 | 29000 | 89000 | 56000 | 66000 |
| Av. daily attendance | 498 | | 674 | | 488 | | 500 | |
| Capacity..... | 52000 | | 52000 | | 52000 | | 52000 | |
| Coefficient... | 470 | | 22 | | 1700 | | 4700 | |

| Day | 5. Copper Sulfate From Feed Pot | | 6. Anhydrous Chlorin From Needle Valve | | 7. Calcium Hypochlorite | | 8. Calcium Hypochlorite | |
|---|---|---|---|---|---|---|---|---|
| | 37 C. | 20 C. | 37 C. | 20 C. | 37 C. | 20 C. | 37 C. | 20 C. |
| 1st........... | 750 | 4000 | 20 | 400 | 1000 | 200 | 1400 | 9200 |
| 2nd........... | 6800 | 28000 | 16400 | 10000 | 2400 | 1600 | 2200 | 3400 |
| 3rd........... | 26000 | 47000 | 202600 | 400000 | 200 | 1400 | 300 | 900 |
| 4th........... | 8000 | 20000 | 160 | 400 | 3500 | 3600 | 6000 | 18000 |
| 5th........... | 15000 | 28000 | 4800 | 36000 | 80 | 6000 | 20 | 5200 |
| Av. daily attendance | 514 | | 1261 | | 493 | | 357 | |
| Capacity..... | 52000 | | 55000 | | 80000 | | 75000 | |
| Coefficient... | 2000 | | 2900 | | 360 | | 86 | |

| Day | 9. Calcium Hypochlorite | | 10. Calcium Hypochlorite | | 11. Calcium Hypochlorite | |
|---|---|---|---|---|---|---|
| | 37 C. | 20 C. | 37 C. | 20 C. | 37 C. | 20 C. |
| 1st.......................................... | 40 | 60 | 250 | 3600 | 200 | 3800 |
| 2nd.......................................... | 500 | 1400 | 1500 | 1100 | 150 | 1400 |
| 3rd.......................................... | 2 | 70 | 20 | 200 | 2 | 180 |
| 4th.......................................... | 70 | 240 | 40 | 50 | 10 | 10 |
| 5th.......................................... | 100 | 1500 | 10 | 1200 | 10 | 9000 |
| Average daily attendance................ | 338 | | 200 | | 130 | |
| Capacity..................................... | 75000 | | 40000 | | 40000 | |
| Coefficient................................ | 86 | | 160 | | 450 | |

Note:—Since the bacterial pollution in a pool varies with the attendance and with the volume of the water in the pool, the coefficient was computed according to the following formula:

$$\text{Coefficient} = \frac{\text{Average daily bacterial count}}{\text{Average daily attendance}} \times \frac{\text{Volume of pool}}{1000}$$

The coefficients are merely rough estimates, but they furnish a simple basis of comparison in determining the efficiency of the different methods of treating the pool.

### CHLORIN GAS

Chlorin gas was injected into tap water which was under sufficient pressure to feed into the pipe leading from the filtering plant to the pool.

The analyses conducted for 1 week on this pool were unsatisfactory because of defective apparatus. According to the engineer in charge of baths, the quality of anhydrous chlorin has deteriorated since the war, frequently containing a heavy oil which is carried over when the chlorin tanks are filled. This oil clogs the needle valve of the injector causing interruption in the flow of the gas. For this reason, the data collected do not indicate the efficiency of chlorin gas for pool-disinfection. In tests on another pool,[1] however, chlorin gas proved to be an efficient and easily handled disinfectant.

### OZONE

Series of tests on ozone applied to drinking water were conducted. This chemical has not yet been applied to the disinfection of swimming pools, but its use would have so many obvious advantages that I have undertaken to experiment with it. While there are no figures as yet on cost of operation or experience of its reliability and ease of control as applied to swimming pools, the tests thus far conducted indicate a very high efficiency on the part of ozone as a purifier of water. Within a short time, I hope to report more extensively on this subject.

### DISCUSSION OF COMPARATIVE EFFICIENCY AND COMPARATIVE COSTS OF THE VARIOUS METHODS

*Copper Sulfate.*—Recently Thomas[2] and Levine,[3] contrary to most observers, concluded that copper sulfate is superior to calcium hypochlorite for the disinfection of swimming pools. Levine reports satisfactory results at Iowa State College, using 1 part of $CuSO_4$ to 1,000,000 parts of water.

The results set forth in this paper show that even when 1 part of $CuSO_4$ to 100,000 of water was used, the bacterial pollution in the pool exceeded that with all other methods of disinfection.

DeWitt and Sherman[4] showed that while very small dilutions of some chemicals destroyed tubercle bacilli, 5% solution of copper sulfate was necessary, even when the time of exposure was 24 hours. In their more recent paper on the subject they conclude: "In the short time of an ordinary laboratory experiment and with the small amount of material usually employed, copper is unreliable and unsatisfactory both as a bactericide and as a fungicide. One percent fails to kill all organisms within 15 minutes."

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[1] Jour. Infect. Dis., 1914, 15, p. 159.

[2] Jour. Ind. and Eng. Chem., 1915, 7, p. 476.

[3] Jour. Infect. Dis., 1916, 18, p. 293.

[4] Ibid., 1914, 15, p. 245; 1916, 18, p. 368.

Johnson and Copeland got unsatisfactory results with sewage effluent even when using 1 part $CuSO_4$ to 25,000 parts of the effluent.

Clark and Gage,[6] after an elaborate study of the effect of copper sulfate in various dilutions on water from various sources, conclude as follows: "In conclusion, the writers believe that the treatment of water with copper sulphate . . . has little practical value for the following reasons:

"I. The use of any method of sterilization which is not absolutely effective is dangerous in the hands of the general user, tending to induce a feeling of false security and leading to the neglect of ordinary precautions which would otherwise be employed.

"II. Although the removal of B. coli and B. typhosus is occasionally accomplished by dilute solutions of copper sulphate, these organisms may both live for many weeks in water containing copper sulphate in greater dilutions than 1:100,000; and in order to be safe dilutions of 1:1000 must be used, in which case the water becomes repugnant to the user because of its strongly astringent taste.

"III. In some instances very dilute solutions of copper sulphate, [e. g., 1:1,000,000 as used by Levine for treating a swimming pool] . . . appear to have a decidedly invigorating effect on bacterial activity, causing rapid multiplication, when the reverse would have been true had the water been allowed to stand the same length of time without any treatment."

The conclusion of Clark and Gage, that high dilutions of copper sulfate are valueless for disinfecting water, agrees with the results which I obtained in the tests on the 23rd Street Baths. Furthermore, as previously stated, copper sulfate costs about $1.04 a day for a 50,000-gallon pool (before the war about 50 cents) when 1 part of $CuSO_4$ is added daily to 100,000 parts of water. The water takes on a yellowish appearance and becomes less transparent. The tiles lining the pool are somewhat discolored.

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[5] Ibid., 1905, Suppl. 1, p. 327.

[6] Ibid., 1906, Suppl. 2, p. 175.

*Anhydrous Chlorin.**—This is the cheapest of the chemicals to use, costing about 0.5 of a cent per day for a 50,000-gallon pool. When it is free from oil, it is easily controlled and very satisfactory to operate. As stated, stoppage of the needle valve and consequent interruption of the flow of gas make the determination of its efficiency impossible in these tests. In tests on another pool, however, it proved highly satisfactory.[1]

*"Lectrocide."**—This costs now 18 cents a day (before the war about 9 cents) for a 50,000-gallon pool. It is easily handled, causes no objectionable odor, and has a high coefficient of disinfection for swimming-pool water.

*Chlorid of Lime, Calcium Hypochlorite.**—This is a very cheap disinfectant and one showing by comparative test a high grade of efficiency. It costs about 8 mills per day for a 50,000-gallon pool. It is more difficult to handle than any of the foregoing chemicals because of its unpleasant odor when improperly added to the pool and because of the stoppage of the filters if the lime sludge is thrown into the filtering circuit. These objections can be easily overcome if the following procedure is adhered to:

Mix the chemical with water thoroughly in a large pail, stirring with a stick so that the active material is brought into solution. Do this in the open air, or in some place remote from the room containing the pool, since, when the chemical is mixed in the room, chlorin gas escapes into the air, causing objection on the part of the bathers to the chemical disinfection.

After the chemical has been thoroughly mixed with water, filter it through cheese cloth into another container, so that the lime sludge can be discarded.

Introduce the chemical into the water at the deep end of the pool through a large pipe extending nearly to the bottom of the pool. A funnel may be needed to pour the chemical in. Do not withdraw the pipe until after pouring some fresh water through it. This method obviates the necessity of pouring the chemical on the surface of the water. The presence of the chemical, either in solution or as a powder on the surface of the water, causes unpleasant odors in the air. Another and simpler method is to drop the pail containing the chemical forcefully into the water. In this way very little of the chemical remains on the surface. With this method and care to prevent odors of the chlorid of lime from escaping into the air, more than a dozen sanctioned Mikveh[7] baths in New York City were treated without complaint from the patrons.

## CONCLUSION

The value of ultra violet light as a disinfectant in swimming pools has not yet been definitely determined. (a) Swimming pools equipped with ultra-violet-light apparatus showed lower bacterial pollution during its use, than before its use. (b) A somewhat longer exposure of the water to the light would seem desirable; in most instances bacterial reduction was not observed after the water had passed through the ultra-violet-light apparatus.

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* Chlorine gas and the hypochlorites were added to the water so that there was 1 part of available chlorin to 1,000,000 parts of water.

[7] Survey, 1914, 34, p. 482.

In regard to the method of adding chemicals to the water, it appears that the value of the slow continuous addition or of the single daily dosing varies with the chemical used. Copper sulfate gave the better results when added gradually and continuously, while sodium hypochlorite gave the better results with single daily dosing.

The relative efficiency of chemicals for water disinfection may be expressed as follows:

(a) Calcium hypochlorite,—high efficiency, low cost, not much care necessary in handling.

(b) Chlorin gas,—efficiency high, cost very low, easily handled.

(c) "Lectrocide",—cost 10 times as much as for hypochlorite, high efficiency, very easily handled.

(d) Copper sulfate,—cost high, efficiency low, stains tiles, causes reduction in transparency of water, easily handled.

Final decision on a standard method for pool disinfection has not yet been reached, and can not be until after ozone and other methods still under investigation, have been fully tested. In the 9 pools examined, refiltration was practiced in all cases, a procedure which should be standard in all indoor pools.